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AUTHOR	Bork, Alfred M.
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ABSTRACT

Basic advice for writing computer dialogs for use in science instruction is given. At the outset one should decide where within the subject area the computer dialog could offer a unique advantage over conventional teaching tools. Examples of such effective uses are remedial programs, in which a computer dialog may rapidly determine a student's particular weaknesses, and the interactive proof, where the student is allowed to demonstrate motivation and originality. In program writing, the model of human dialog is an effective tool. The goals, the style and the structure of student-computer dialogs are discussed, with samples of good dialog usage included in the appendix. (RB)

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THE COMPUTER IN LEARNING--ADVICE TO DIALOG WRITERS

Alfred M. Bork

Physics Computer Development Project
University of California
Irvine, Cal. 92664

May 24, 1971

physics computer development project, university of california, irvine, 92664

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LEARNING--ADVICE TO DIALOG WRITERS

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California
2664

roject, university of california, irvine, 92664

By a dialog we mean here a "conversation" between a student and a teacher, where the teacher is conducting the dialog through a medium of a computer program. Typically a dialog of this kind follows a pattern such as this. First, something will be typed to the student, possibly some information. Then the student will be asked to reply. Depending on what the studnet put in, a number of things might be typed to him next. Several samples with student input underlined, are included in the appendix.

Here we want to offer some crude advice to those attempting to write such student-computer dialogs. Writing a student-computer dialog is a little understood process at present, so <u>any</u> advice should be considered as subjective, and should not be taken too seriously! Nevertheless some tentative experience can be brought to the attention of the teacher who is working on such material. This document attempts to do this, using the experience in the Physics project at the University of California, Irvine, as the basis.

SUBJECT AND TYPE

One early decision the dialog writer, the teacher, must face is what to write dialogs about. At present the use of computer based dialogs is experimental and untested. In many areas little concrete evidence exists to show that dialogs can do a more effective job in teaching students that other methods, although many of us believe this to be the case in some situations. Hence, the burden of educational proof is on the dialog writer. He cannot assume that simply because he puts standard existing material into dialog form in trivial ways that he is improving the teaching situation. Furthermore, the preparation of extensive dialogs is a lengthy job, putting a premium on making wise choices as to what to write a dialog about.

One way to approach the problem is to ask where one could, within the teaching of a particular subject area, gain some unusual leverage with computer dialogs. The answer to this question would perhaps be different for different areas, and could only be given by someone with an extensive knowledge both of subject and pedogogy. It does seem important to ask the question, and to concenocument attempts to do this, using the Physics project at the University vine, as the basis.

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trate dialog efforts in areas that look promising for this technique. It is reasonable to debate with colleagues as to where the effort whould be concentrated.

A dialog which recreated a book, or a printed program text, or some other teaching method, is not likely to have long survival value. Perhaps when the cost of computer usages is considerably less than it is today, and when we become more knowledgable in the use of computers, the computer may replace the text, but this is far in the future. A corollary is that it is too early to prepare a complete computerized course; we should concentrate on small segments and study their effectiveness. Innovation in many directions is still essential here.

A class of powerful dialogs are the remedial dialogs which try to determine the students' weaknesses in an area, and give him assistance just where it is needed. One useful trick is to begin by assuming that the student does know the area, giving him a series of questions which selectively test his knowledge, perhaps by working examples. These problems need not be difficult; if they are to be repeated they can be "generated" by means of a problem generating sequence. The student will only be sent into the remedial parts of the diagram if he cannot handle these problems after several attempts (to allow for the usual typing errors). This approach has the advantage that the student receives assistance only in those areas where he is weak, so the program can be responsive to his needs. One variant of this is the dialog which tries to assist the student who has had trouble working a problem, finding where he had trouble and giving him help.

Another area of the sciences where we think that dialog material will be particularly effective is that of the interactive proof or problem. The idea is to allow the student to try to prove some of the important results of the course partially on his own, making choices and guesses along the way, perhaps in response to suggestions in the program; thus the process of developing difficult proofs can be made on active process rather than the passive one of listening to a lecture. Similarly, a problem at the computer has advantages over a text book problem; you can, for example, make the student <u>ask</u> for information, rather than giving it all to him in advance as in the typical textbook problem. So he must decide what information is relavant.

<u>MECHANISM</u>

How should the dialog writer work? As with matters of style this is very individualistic, and further will be

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heavily dependent on the facilities available. All that is attempted here is to mention and comment on some of the possibilities.

After the basic area has been chosen the author will make at least a brief outline of his "mainline" approach, showing the material to be covered. A one-page outline is often useful.

Some authors will develop the mainline almost fully, with the messages that will be typed to the student in full detail. Then they will go back and fill in bad branches and loops, or other mainlines. However, some teachers prefer to work on a "frame by frame" basis, outlining the principle development briefly, and then going sequentially through the program branches along the way. My own preference is for the second style, although with very complex dialogs the sequential approach may present a problem in keeping straight as to where one is along the process! The second approach has a psychological advantage in that it makes the teacher think <u>all along</u> as to how to respond to the student who is confused or who does not know hat he is doing, while the mainline approach may lead one to be impatient in filling in the details.

Another aspect is the author's relation to programming language or languages involved in the final preparation of the material. A good many variants are possible. First there is what might be termed the "Coursewriter approach", the one the original developers of the Coursewriter language in IBM seemed to have in mind. This involves the author, the teacher, in using the language itself in writing the dialog, writing statements directly in that language as he thinks his way through the program. Many such languages exist, but most have seen little usage; Coursewriter has seen wide use.

A second approach is for the teacher to work in developing the dialog in a (modified) flow chart form, in a way that does not depend on the details of computer mechanism to be used; a variant is to use decision tables. The teacher sketches out the conversation by a series of boxes, divided lines, and other graphic aids, showing what he wants to "say" to the student, what responses he wants to handle, the messages typed or displayed for each response, etc.

A third possibility is the use of a facility that prompts the instructor, sitting at a terminal, for the various pieces of the dialog that will be necessary, like the Scholar-Teach system or the Ditran system developed by Noah Sherman at the Lawrence Hall of Science at Berkeley.

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Again I briefly state that my own preference is for the second way, both because it removes the teacher from the computer details and also because it allows him maximum freedom to do _what_ he wants to do within the program without worrying about _how_ to do it.

Either typing at a terminal or key punching is possible, depending on the computer system employed. Since dialogs are to be used on time-sharing systems it is advisable to use the often powerful editing capabilities of such systems to assist in the preparation of the dialog material; so on-line entering and correction of programs is desirable except where it is ruled out by financial considerations or by system unveliability.

The ideal individual for typing or keypunching seems to be the trained secretary, rather than a programmer, a student, or a teacher. Programmers and teachers in general are _not_ good typists. Anyone who is acquainted with dialogs knows that a vast amount of time must be spent in typing the material, since much of it is the text to be shown to the student. It is not difficult to train secretaries to use computer terminals and to work in well-designed programming languages and editing systems.

GOALS

Perhaps some brief comments should be offered concerning short term versus long term goals; in any teaching activities we should decide what we are trying to do. If we consider a science course, there may be a factual piece of information at a point in the course that the student is to learn--the standard theories that already exist in the area, the mathematical techniques that go along with these theories, etc. But our interest in science teaching is not all archival, intended to persuade people to look admiringly at these lovely mental structures of past science. Rather we hope to produce people who can go ahead and use this information in one way or another, modestly in developmental work or in great creative leaps beyond the present situation in science. Teaching factual material is one task, but being able to use it is often a different matter. The moment of truth for a student in a science course comes when he is asked to work difficult problems, problems which demand that he take the information and techniques presented and obtain new information. The long range goal of most science courses is to produce people who can make some of these developments themselves.

Long range teaching goals should be kept in mind by the dialog writer, and stressed in whatever way possible. It is very easy to ignore them, because they present much greater teaching difficulties than the mere

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presentation of information. Teaching students to successfully tackle difficult problems is a hard task. The heuristic strategies involved in problem solving, for example, are seldom discussed with the students (a glowing exception is George Polya's book, How to Solve It).

Although these comments on goals are directed toward science courses, the consideration is important in curriculum development in all areas.

STYLE

It is unwise to be doctrinaire about style, even more so than in the rest of this discussion, because style is so individualistic. It seems reasonable that dialogs should not always be in the same style; different people have different ways of writing.

One tendency is to approach the problem of writing student-computer dialogs as if writing a text or a paper. But the difficulties are really greater with dialog material, and the style of the dialog should reflect these differences and difficulties. With a text most of the concern is with the "main line"; the right way of handling the developing material. Usually only one main line is considered, although occasionally alternate proofs may be given. A dialog may not only include multiple main lines, to react to different ways the students may proceed, but it must also spend a great amount of energy and effort in sections that never appear in texts--wrong approaches, mistakes which you should respond to in some reasonable way, remedial assistance for a student who is having mathematical difficulty: If computer-student dialog is to prove valuable it will need to be more responsive to student needs than a static text book. This means that the non-main line sequences are extremely important for the dialog; much of the time typical students are likely to be in these areas of the program.

Most of us feel that dialogs should resemble a conversation in some way: The name dialog suggests the model of the student conversing with the teacher in his office; the teacher asks questions which are designed to help the student learn the material. Clearly we cannot fully realize with the computer, the model of the office conversation and some people object to trying to make a computer dialog look like a student-teacher discussion. However, it seems possible to follow this model to some extent; my own tendency is to believe this is a viable approach.

The model of human dialog suggests that computer dialog style should be more like that of a conversation, and less like that of a book. Talking is more informal than

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writing, and often more redundant. Humor, and light touches, are desirable and welcome, although experience shows that not everybody agrees as to what is humorous! Informal language, as opposed to elaborately structured and carefully formulated sentences, is desirable. While some people talk in long and involved sentences, the type that one sees in learned articles, this is rather rare, even among college instructors!

Another issue in which dispute exists, but little <u>empirical</u> evidence, is the question of the use of a first person style. Most of the dialogs developed at Irvine have used the first person style, while most of those from Berkeley on the Irvine system have not. The Irvine students, when queried about the first person style, supported its use. But this does not demonstrate that such a style is necessarily desirable. More information is needed, perhaps through psychological studies, as to whether the computer should be typing "I". Currently we are running one dialog with two branches, randomly chosen, one of which uses the first person, one not.

The student has a number of ways of interpreting such an "I" in a computer dialog. He may think of it as the author of the program, rather than the computer itself. You can, if you want to in your dialogs, identify who you are, and this might make "I" more natural.

More generally the question of how style influences student response is undetermined. It has been suggested that relatively small changes in style, in for example technical vocabulary, may have considerable influence on student output, but no evidence exists; again this year we are running a randomly chosen two branch dialog to explore this question.

Perhaps one of the hardest things for the teacher to keep in mind in preparing a dialog is that he has very limited facilities at his disposal for analyzing the student response. Even a carefully organized and prepared dialog will often miss the meaning of what the student is typing, even though the dialog has already been improved from past student usage. The computer is <u>not</u> a person, and does not have all the resources for dealing with the students' comments of an actual teacher. Largely we identify responses by string matches, looking for key words or letters in the input. Even with elaborate care for different types of string matches, we cannot react accurately to everything the student says, and certainly we cannot currently approach the capabilities of human beings. Care in how the questions are stated is valuable, but does not do the entire job.

This weakness indicates that a degree of humility and modesty is required in the response to student comments,

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particularly the comments which we have been unable to analyze and which we presume to be wrong. To tell the student unequivocally that he is wrong is often dangerous, except in environments where the response is carefully controlled by the situation, or where extremely detailed analysis of the input is made. Your program may be missing an unusual variant of a right answer.

Along with the previous suggestions a pedagogical point seems reasonable. A tendency exists, particularly with impatient individuals, to be scornful of the students lack of success in a particular place in the program. I think it fair to argue that abusive language, or language which questions the student's intelligence, is seldom desirable in a teaching situation, either in direct conversation, text, problem grading, or dialog. Thus it is not desirable or reasonable to call a student "stupid" because he did not put in the response you were looking for at a particular place.

A tendency exists in employing technological aids to education to allow the technology to control. This seems to be a mistake; the teaching aims and teaching purposes should always be in the forefront. Thus in applying computers to physics one should resist the temptation of being guided by the facilities available. Rather the primary emphasis should be on what you want to teach and how you want to teach it, the pedagogical aspects. Ideally the author should develop the dialogs without much regard to the details of how they are going to be put on the machine, although he needs to have some background of what is possible with the computer. Pedagogy should take presidence over technology in all cases.

A stylistic tendency noticeable in some new writers of computer based teaching material is to spend too much time in talking with the students, accepting only trivial responses and typing long messages. We might call this the "textbook disease". There are places where one does want to type long messages, or interact only minimally, but a dialog which does only this is not worth putting on the computer, since it becomes a book typed to the student. A dialog writer should ask how he can involve the student in a different way than a book would involve him, getting him to make meaningful responses which contribute toward learning. Interesting sidelines involving much typing can be made optional; thus, in a physics dialog, historical discussion of the issues may not be of interest to all students, but may interest some. Letting the students make a choice in such situations seems reasonable, and increases the flexibility of the material. Similarly, a review might be optional for the student who has done well, but automatic for the student who has not.

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In many instances it is reasonable to allow a student several attempts at the answer, perhaps even a large number of attempts. There should, however, be an eventual exit in all cases, to avoid having the student trapped at some point and not knowing what to do to get out of the trap. Setting of counters and testing on counters can allow flexible looping for additional tries. You can have a series of hints, successive pieces of advice, which can be given to students not putting in the expected results.

You can give advice particularly tailored to things that the student is typing that seem to be wrong. For example, if you are expecting an equation and the student is not entering an equal sign or some equivalent word, then you could stress that you are looking for an equation, and not identifying it in his input. You may expect a formula or equation that contains certain symbols, but those symbols are not present; hence based on the information about what is missing it may be useful for the student to try the question again. If the student has part of the answer, but is missing some things he can be asked to enter only the aspects previously missing; don't require more typing than is necessary.

In looking for verbal input, it is often a good policy to look for only part of each key word, thus bypassing some of the problems of bad spelling or bad typing. You might also look for likely mispellings; this is much easier to do when you are revising the dialog.

The amount of retries and specialized advice can of course vary from place to place within the dialog. With some important results it may be good to give the student many many attempts, but in other cases it may be unreasonable to do this. The dialog author can spend an infinite amount of time on any one question in the program in an attempt to analyze the student response. But he should use judgement as to where a point of diminishing return is reached, usually a pedagogical decision. The author should also be prepared for the fact that if he has an extremely complicated analysis at a particular spot, involving many tries, and many pieces of specialized advice for wrong inputs from students, programming errors become more and more likely as the complexity grows.

It is not always necessary to do an analysis of the student's input. In some situations the program can simply accept the input and go on. Thus, it might be that you will want to get the student to think about the material, and to have some pause in between sections of material. Or you may want him to make an input but

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you may intend to say the same thing no matter what he enters. Another situation in which the nonanalyzed input is of value is with student comments. Dialogs should usually invite long comments from the student at the end, and presumably these may be too complex to allow any immediate reply. Another related valuable device, useful in providing feedback to the teacher as to the teaching success of the program, is to ask for a long verbal description or summary of the situation being studied. Thus, in a dialog involving standing waves on a string, we can ask the student to describe what a standing wave is, and what types of standing waves are possible; if the program has worked him through the first normal mode he can for example describe the second normal mode. Such a long entry, involving many lines, could not presently be analyzed in a very meaningful way, although one might still choose to respond to some key words. But the teacher can examine these detailed comments and determine if they do in fact indicate that most students understand the material that he has tried to cover. This mechanism can also be used for getting feedback to the students. A student can be asked to sign his questions or queries, with the promise that the reply will be coming soon.

One stylistic question on which there is not universal agreement is the necessity for what the behavioral psychologist calls "positive reinforcement". A view which is supported by many psychologists and teachers is that when a student makes the right response he should always be told that he is right. However, others argue that we do not do this in normal conversation, and so are not willing to do it at all times. One can of course have compromise positions, sometimes responding favorably to correct answers, sometimes not. I tend to believe that it should be done frequently but not all of the time.

A place in dialog writing where imagination tends to be limited is the constant need to say the same basic thing over and over, but in different ways. The typical situation is "try again", the response that the student should attempt the question at least one more time. Congratulating him on a right answer is another similar situation, reinforcing his response. It is convenient to have built in facilities to vary the choice here.

One of the most important aspects of the dialog is the ability to respond reasonably to the wrong answers. If a student says something which is wrong and you can tell him why it is incorrect, and perhaps give him another try, then the dialog is serving an interactive function. In thinking about the possible responses for every question the teacher needs to consider what the student

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can say that is not right, and what response is reasonable. This is not necessarily easy, and some discussion with others may help. Good dialogs often devote more of the program to respond to wrong answers than to the mainline material, sometimes dramatically more. Don't worry about how the professionals can slip by; the dialogs are written for <u>students</u>.

<u>Feedback</u>

It has already been suggested several times that feedback from student use of the dialogs can be important in improving the dialogs for later groups of students. This is indeed a very powerful tool, one of the main hopes in producing dialogs which will be an effective teaching device. Dialogs as initially written, even the best ones available today, are not very successful in dealing with student response, so feedback is critical.

The question of <u>what</u> feedback is wanted from student use of the dialog, and how the feedback is to be used, should be carefully considered in advance. The dialog should be consciously planned to give internally the kind of information that is useful in analyzing students' responses, using this information to improve the next version. One must be careful not to bury oneself under too much information, for example, but to get that information that is <u>relevant</u> to improving the dialog.

Normally in the physics conversations developed at Irvine we have found it reasonable not to save all student responses, because with large student usage so many of these would be obtained that they could not be analyzed successfully. What is usually helpful in improving the conversation are responses that could not be responded to either favorably or unfavorably. Some of these responses may be right answers, but answers that your matching program was too crude to find. Others may give further suggestions as to what students are likely to say that is wrong, and that should be commented on. The saved responses may also indicate areas in the program which are extremely weak, and which need to be extended, or may indicate ambiguous terminology in the question being put to the student, or a poor stylistic approach. They can even indicate that the student's use of the English language is at variance with the teacher's uses. In saving responses it is valuable to store also information which allows you to identify the responses by who entered them. Thus some insight into the problems of the dialog may be obtained by watching the progress of individual students.

The author should also consider whether he wants to keep a numerical record or performance during the dialog--how many things the student got right, which e physics conversations developed at found it reasonable not to save all ses, because with large student usage e would be obtained that they could d successfully. What is usually helpful he conversation are responses that could ed to either favorably or unfavorably. responses may be right answers, but our matching program was too crude to may give further suggestions as to what ikely to say that is wrong, and that ented on. The saved responses may also in the program which are extremely weak, to be extended, or may indicate ambiguous the question being put to the student, or ic approach. They can even indicate that use of the English language is at vari- teacher's uses. In saving responses it store also information which allows you e responses by who entered them. Thus nto the problems of the dialog may be tching the progress of individual

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loops he got into, etc. Again, some thought in advance as to what information should be gathered during the student performance, and how that information is going to be analyzed, is important.

The author needs access to convenient sorting programs in handling these responses, sorting both on the location within the program at which the input was obtained and on the inputs associated with each student. The results, with a large class will be extensive; with this output the author can then set to work on the next, and better, generation of the dialog.

APPENDIX

SAMPLES OF DIALOG USAGE

Student input underlined.

- [illegible] NAME? [illegible]

PLEASE TYPE AN IDENTIFICATION
- 7 CHARACTERS OR LESS - - - ALFRED

PHYSICS:SB: QUIZ/2

THE FOLLOWING QUESTIONS (20 IN ALL) ARE
CONCERNED WITH THE DIRECTIONAL PROPERTIES
OF MAGNETIC FORCES AND MAGNETIC FIELDS.

IF YOU DO NOT KNOW THE ANSWER TO A
QUESTION AND DON'T WANT TO GUESS, STRIKE
A CARRIAGE RETURN.

WHEN READY TO PROCEED, HIT 'RETURN'.

PART I (QUESTIONS 1-5) BAR MAGNETS AND COMPASSES.

>>>>1. TWO BAR MAGNETS ARE ARRANGED AS
SHOWN HERE.

```
*-------------*    *-------------*
!N           S!    !N           S!
*-------------*    *-------------*
```

DOES THE MAGNET ON THE LEFT EXPERIENCE
    A. NO NET FORCE
    B. A NET FORCE TO THE RIGHT
    C. A NET FORCE TO THE LEFT
OR IS IT CAUSED TO ROTATE
    D. CLOCKWISE
    E. COUNTERCLOCKWISE
PLEASE RESPOND WITH A SINGLE LETTER:
A, B, C, D, OR E.

?D

NO. REAL LIFE MAGNETS, NOT IDENTICAL AND NOT
PERFECTLY ALIGNED, MIGHT TEND TO ROTATE. OUR
IDEAL MAGNETS ARE IDENTICAL AND PERFECTLY
ALIGNED. TRY AGAIN.

?C

NO.
[illegible] NET FORCE IS TO THE RIGHT. THE CLOSER
[illegible] UNLIKE AND ATTRACT.

[illegible]
THE PAIR NOW LOOK LIKE THIS:

```
*--------------*    *--------------*
!N            S!    !S            N!
*--------------*    *--------------*
```

DO THE MAGNETS ATTRACT, REPEL, OR TEND TO ROTATE?

?REPEL, I THINK

RIGHT.
THE MAGNETS REPEL. THE PRINCIPAL EFFECTS COME FROM THE LIKE POLES CLOSEST TOGETHER.

```
>>>>3. NOW WE ARRANGE OUR
IDENTICAL MAGNETS IN  *---*     *---*
THIS FASHION. IS      ! N !     ! S !
THERE ANY NET         !   !     !   !
FORCE BETWEEN         !   !     !   !
THEM?                 !   !     !   !
                      !   !     !   !
                      !   !     !   !
                      !   !     !   !
                      !   !     !   !
                      ! S !     ! N !
                      *---*     *---*
```

?YES

CORRECT.
IS THE NET FORCE ATTRACTIVE OR REPULSIVE?

?ATTRACTIVE

THAT'S RIGHT.
THE UPPER PAIR OF UNLIKE POLES ATTRACT, AND SO DO THE LOWER PAIRS.
INCIDENTALLY, AS THE MAGNETS ARE DRAWN TOGETHER, DO THEY ROTATE?

?NOT IN THE IDEAL CASE

THAT'S RIGHT.
THERE IS NO NET TORQUE.

```
[illegible]                    ↑ ↑ ↑
[illegible]                    ↑ ↑ ↑
ITS CENTER AND FREE            ↑ ↑ ↑
TO MOVE IN ANY DIRECTION.      ↑ ↑ ↑
IT IS PLACED IN A              ↑ ↑ ↑
VERTICAL MAGNETIC FIELD        ↑ ↑ ↑
AS INDICATED BY THE            ↑ ↑ ↑
ARROWS AT THE RIGHT.           ↑ ↑ ↑
LET'S TRY A COUPLE             ↑ ↑ /
OF YES/NO QUESTIONS            ↑ ↑/ S
FIRST, DOES THE                ↑ ↑ *
MAGNET EXPERIENCE A            ↑ ↑ ↑
NET FORCE?                     ↑ ↑ ↑
```

?YES

NO, IT DOES NOT.
THE NORTH AND SOUTH POLES EXPER
EQUAL AND OPPOSITE FORCES.
SECOND, DOES THE MAGNET EXPERIEN
TORQUE?

??

PLEASE TYPE A SINGLE WORD, YES O

?NO

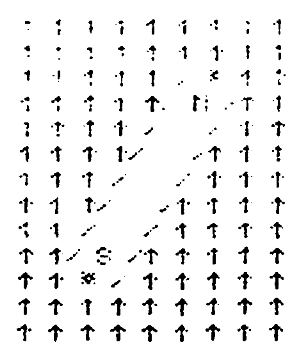
IN FACT, IT DOES TEND TO ROTATE.

>>>>5. BECAUSE OF THE TORQUE, TH
TO ALIGN ITSELF IN THE FIELD. IN
ABOVE (WITH QUESTION 4), WILL TH
UNTIL ITS NORTH POLE IS AT THE T
RIGHT, OR BOTTOM?

?STOP

USE THE SAME IDENTIFICATION NEXT
YOU USE THIS PROGRAM.
YOUR IDENTIFICATION WAS ALFRED
GOODBYE

OUR BAR MAGNET,
PIVOTED AT
ITS CENTER AND FREE
TO MOVE IN ANY DIRECTION.
IT IS PLACED IN A
VERTICAL MAGNETIC FIELD
AS INDICATED BY THE
ARROWS AT THE RIGHT.
LET'S TRY A COUPLE
OF YES-NO QUESTIONS
FIRST, DOES THE
MAGNET EXPERIENCE A
NET FORCE?



?YES

NO, IT DOES NOT.
THE NORTH AND SOUTH POLES EXPERIENCE
EQUAL AND OPPOSITE FORCES.
SECOND, DOES THE MAGNET EXPERIENCE A NET
TORQUE?

??

PLEASE TYPE A SINGLE WORD, YES OR NO.

?NO

IN FACT, IT DOES TEND TO ROTATE.

>>>>5. BECAUSE OF THE TORQUE, THE MAGNET TENDS
TO ALIGN ITSELF IN THE FIELD. IN THE DIAGRAM
ABOVE (WITH QUESTION 4), WILL THE MAGNET SWING
UNTIL ITS NORTH POLE IS AT THE TOP, LEFT,
RIGHT, OR BOTTOM?

?STOP

USE THE SAME IDENTIFICATION NEXT TIME
YOU USE THIS PROGRAM.
YOUR IDENTIFICATION WAS ALFRED
GOODBYE

[illegible] NAME [illegible]

PLEASE TYPE AN IDENTIFICATION
7 CHARACTERS OR LESS - - - ALFRED

LET'S LOOK AT THE ALGEBRA OF COMPLEX NUMBERS.

WHAT IS

(2+3*I) + (7-8*I)

EQUAL TO?

?-5I +9

LOOKS FINE....

NOW LET'S TRY SOME MULTIPLICATION OF
COMPLEX NUMBERS.

WHAT IS:

(4+2*I)*(-2+3*I)

EQUAL TO?

?-13-3I

I DON'T FOLLOW YOU. TRY AGAIN.

WHAT IS:

(4+2*I)*(-2+3*I)

EQUAL TO?

?-13+8I

I CAN'T RECOGNIZE YOUR RESPONSE. MULTIPLICATION
OF COMPLEX NUMBERS IS VERY SIMILAR TO
MULTIPLICATION OF POLYNOMIALS.

(A+B)*(C+D)=A*C +A*D +B*C +B*D.

O.K. NOW TRY AGAIN.

WHAT IS:

(4+2*I)*(-2+3*I)

EQUAL TO?

?-14+8I

THAT'S IT!

[illegible] ADD AN
COMPLEX NUMBERS. LET'S [illegible]
FEW OF THEIR PROPERTIES.

NOTE: I WILL USE THE NOTA

EXP(X)

TO DENOTE THE NUMBER "E"
POWER X WHERE "E" IS THE
BASE. (E=2.71828......)

CAN YOU ENTER THE REAL PA
COMPLEX NUMBER:

EXP(I*PI/3)

WHERE PI EQUALS THE USUAL
AND I=SQR(-1).

?NO

ARE YOU FAMILIAR WITH COM
EXPONENTIALS?

?NO

THE FUNDAMENTAL RELATION

EXP(I*X)=COS(X)+I*SIN(X)

I'M GOING TO ASK YOU TO A
A MATHEMATICAL FACT WITHO
LET'S PRACTICE USING IT H

WHAT IS:

EXP(I*PI)

EQUAL TO?

?STOP

USE THE SAME IDENTIFICATI
YOU USE THIS PROGRAM.
YOUR IDENTIFICATION WAS A
GOODBYE

```
[illegible] ADD AND MULTIPLY
COMPLEX NUMBERS.  LET'S EXPLORE A
FEW OF THEIR PROPERTIES.

NOTE: I WILL USE THE NOTATION

     EXP(X)

TO DENOTE THE NUMBER "E" RAISED TO  THE
POWER X WHERE "E" IS THE NATURAL LOGARITHM
BASE.   (E=2.71828......)

CAN YOU ENTER THE REAL PART OF THE
COMPLEX NUMBER:

   EXP(I*PI/3)

WHERE PI EQUALS THE USUAL 3.14159.....
AND I=SQR(-1).

?NO

ARE YOU FAMILIAR WITH COMPLEX
EXPONENTIALS?

?NO

THE FUNDAMENTAL RELATION WE NEED IS

EXP(I*X)=COS(X)+I*SIN(X)

I'M GOING TO ASK YOU TO ACCEPT THIS AS
A MATHEMATICAL FACT WITHOUT PROOF....
LET'S PRACTICE USING IT HOWEVER.

WHAT IS:

    EXP(I*PI)

EQUAL TO?

?STOP

USE THE SAME IDENTIFICATION NEXT TIME
YOU USE THIS PROGRAM.
YOUR IDENTIFICATION WAS  ALFRED
COOKIE
```

CATION

```
GET DIALOG
  -  PROGRAM NAME? HARMONIC

LEASE TYPE AN IDENTIFICATION
 7 CHARACTERS OR LESS - - -  BLEEFD

HAT IDENTIFICATION HAS BEEN USED BEFORE.
AS IT BY YOU?

?YES

E WILL CONTINUE FROM WHERE YOU LEFT OFF


 AM PROGRAMMED TO DISCUSS HARMONIC OSCILLATORS
AND THEIR 'EQUATIONS OF MOTION', BUT FIRST
 WOULD LIKE TO DISCUSS THE FORCES EXERTED BY
SPRINGS.  IF YOU FEEL THAT THIS ISN'T NECESSARY
TYPE 'GO ON' AND WE WILL PROCEED WITH THE
HARMONIC OSCILLATOR PROGRAM.  IF YOU ARE NOT
FAMILIAR WITH SPRINGS JUST PRESS 'RETURN'

?GO ON

A HELICAL SPRING IS A CLASSIC EXAMPLE OF
A PHYSICAL SYSTEM THAT OBEYS HOOKES'S LAW.
LET F= THE FORCE EXERTED BY THE SPRING WHEN
IT IS STRETCHED AN AMOUNT X; LET K= THE FORCE
PER UNIT STRETCH (THE SPRING CONSTANT).
WRITE AN EQUATION EXPRESSING HOOKE'S LAW:
     F= K X

IF THE SPRING IS STRETCHED TO THE RIGHT,
THE RESTORING FORCE IS TO THE LEFT.
TRY AGAIN
     F=  - K * X

VERY GOOD. THE MINUS SIGN IS QUITE
IMPORTANT.
```

```
!///!    UNSTRETCHED
!///!
!///!---SPRING-SPRING-SPRING-SPR
!///!
!///!
!///!    STRETCHED
!///!
!///!---SPRING-SPRING-SPRING-SPR
!///!
!///!
NOW THE FORCE EXERTED BY A STRET
COULD BE USED TO ACCELERATE SOME
EXAMPLE, WE COULD IMAGINE ONE EN
SPRING CLAMPED TO A RIGID WALL A
M ATTACHED TO THE OTHER. SUPPOSE
THE MASS A DISTANCE X TO THE RIG
RELEASE IT. AN EQUATION CAN BE W
ALLOWS US TO PREDICT THE SUBSEQU
OF THE MASS. WRITE SUCH AN EQUAT

?F=MA

O.K. BUT THAT EQUATION IS QUITE
HOWEVER, I'M LOOKING FOR AN ADAP
THE LAWS OF MOTION TO OUR PARTIC
PROBLEM. WHAT IS THE EQUATION FOR
FORCE?
     F=   -KX

RIGHT.
SO FOR OUR PARTICULAR PROBLEM
WE COULD WRITE-K*X=M*A


BUT LOOK HERE: X MEASURES BOTH TH
CHANGE IN LENGTH OF THE SPRING AN
DISPLACEMENT OF THE MASS. SO FOR
VELOCITY WE COULD WRITE
     V=DX/DT=X'
WRITE AN EQUATION FOR THE ACCELER
     A=X''

EXCELLENT.
I HOPE I'VE BEEN INTERPRETING YOU
CORRECTLY. I'VE BEEN PROGRAMMED T
RECOGNIZE THAT
     V=DX/DT=X'
AND -
     A=DV/DT=X''
```

```
!///!     UNSTRETCHED
!///!
!///!---SPRING-SPRING-SPRING-SPRING--  M >
!///!
!///!
!///!     STRETCHED
!///!
!///!---SPRING-SPRING-SPRING-SPRING-SPRING---< M >
!///!                                       !---X---!
!///!
```

NOW THE FORCE EXERTED BY A STRETCHED SPRING
COULD BE USED TO ACCELERATE SOMETHING. FOR
EXAMPLE, WE COULD IMAGINE ONE END OF THE
SPRING CLAMPED TO A RIGID WALL AND A MASS
M ATTACHED TO THE OTHER. SUPPOSE WE DISPLACE
THE MASS A DISTANCE X TO THE RIGHT, SAY, AND
RELEASE IT. AN EQUATION CAN BE WRITTEN THAT
ALLOWS US TO PREDICT THE SUBSEQUENT MOTION
OF THE MASS. WRITE SUCH AN EQUATION.

?F=MA

O.K. BUT THAT EQUATION IS QUITE GENERAL.
HOWEVER, I'M LOOKING FOR AN ADAPTATION OF
THE LAWS OF MOTION TO OUR PARTICULAR
PROBLEM. WHAT IS THE EQUATION FOR THE
FORCE?

F= -KX

RIGHT.
SO FOR OUR PARTICULAR PROBLEM
WE COULD WRITE-K*X=M*A

BUT LOOK HERE: X MEASURES BOTH THE
CHANGE IN LENGTH OF THE SPRING AND THE
DISPLACEMENT OF THE MASS. SO FOR THE
VELOCITY WE COULD WRITE

V=DX/DT=X'

WRITE AN EQUATION FOR THE ACCELERATION:

A=X''

EXCELLENT.
I HOPE I'VE BEEN INTERPRETING YOU
CORRECTLY. I'VE BEEN PROGRAMMED TO
RECOGNIZE THAT

V=DX/DT=X'

AND -

A=DV/DT=X''